OBSERVATIONS ON THE ECOLOGY OF THE SOUTH AFRICAN UMBILICARIAE.

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Until recently, only two species of Umbilicaria, *U. papulosa* Ach. var. *rubiginosa* and *U. membranacea* Laurer apud Nyl., were known from South Africa. Subsequent collecting, including that by the author on an expedition to the Central Cedarberg, led to the discovery of many more. These specimens were recently described by Frey (1949) and included four new species.

HABITATS OF THE SOUTH AFRICAN UMBILICARIAE.

The genus Umbilicaria in South Africa appears to be restricted to the mountain ranges in the sub-continent. These saxicolous lichens are usually confined to montane habitats in tropical or sub-tropical regions but may occur at lower altitudes in temperate regions. In South Africa, Umbilicariae have been found on Table Mountain, mountains in the Ceres and Worcester divisions, the Swartberg, the Cedarberg and the Natal Drakensberg. They probably also occur on other mountain ranges in South Africa.

Meteorological records from the summits of these mountains are scant. The mountains in the Cape south-western region occur in the winter rainfall area while the Natal Drakensberg lies within the summer rainfall area. On Table Mountain, the total annual rainfall at the Cableway Station (3,497 ft. alt.) is known to vary between 40 and 50 in.; that at Maclear's Beacon (3,582 ft. alt.) may be over 80 in. Precipitation on and about the summit plateau of Table Mountain is considerably higher than at lower altitudes on the northern or western sides. Furthermore, the summit is often covered by the "tablecloth" cloud.

No records are available for the higher parts of the Cedarberg. The forestry station at Algeria, in the valley below the Middelberg ridge, receives between 19 and 30 in. per annum, but it is probable that the annual rainfall on the peaks is over 40 in. The total annual rainfall on the peaks of the other ranges in the south-western region is probably of the same order. The higher peaks of the inland mountains are frequently bedecked with snow during the winter.

The climate of the higher regions of the Natal Drakensberg is also imperfectly known. The station, Tryme, in the foothills (4,900 ft. alt.) has a total annual rainfall varying between 36 and 77 in., with an average annual rainfall of 52·57 in. over a period of ten years. The rainfall on the summits is probably higher. Snow usually falls on the summit plateau during the dry winter season and atmospheric temperatures below −10°C. have been recorded near the escarpment edge during July.

TABLE MOUNTAIN.

The most common species of Umbilicaria on the Cape Peninsula is *U. papulosa* var. *rubiginosa.* It is frequent on exposed Table Mountain Sandstone faces of various angles of slope. The thalli, which normally bear apothecia, are either grey or red-brown. They are usually small (± 2 cm. diam.) occurring singly or in aggregates of smaller thalli. Groups of the two colour variants appear to be mixed throughout the distribution area of the species on the mountain. The two colour variants do not seem to exhibit any clearly delimited ecological preferences.

U. papulosa var. *rubiginosa* on Table Mountain is confined to the summit and uppermost faces of the massif. (i.e. 3,400—3,580 ft. alt.) Since its area of distribution coincides roughly with that area periodically covered by the "tablecloth" cloud, it seems probable that the distribution of this species is determined by the more or less frequent occurrence of mist, which could provide a supply of water to the thalli, besides that obtained from rain.

A species that apparently demands a much moister environment is *U. dilacerata* Frey, recorded from below Fountain Ledge on a shaded boulder within the spray of a waterfall at 3,000 ft. alt. As Frey (1949) points out, it is remarkable in that very few Umbilicariae live under such moist conditions. The thalli bear copious ripe spores, despite the fact that hygrophilous species fruit less frequently with an increasingly wet environment.

MOUNTAINS OF WORCESTER DIVISION.

The Waaihoek mountains provide a habitat for *U. capensis* Frey, *U. cylindrica* (L.) Ach. and *U. polyphylla* Hoffm. f. *lacera* at an altitude of about 5,000 ft. Sandstone substrates are frequent and the higher regions are often snow-covered in winter. *U. cylindrica* and *U. polyphylla* also occur in the sub-alpine and temperate zones of South Island, New Zealand, respectively.

U. membranacea has been recorded in a fruiting condition from above Du Toit's Kloof between the Witteberg and Molenaarsberg at 2,500 ft. alt. on rocks in a streambed which are submerged during floods. Besides its occurrence in this hydric situation it grows on boulders at 2,500 ft. alt. near Somerset West and also on Sneeuwkop at 3,500 ft. alt. on boulders under trees.

SWARTBERG.

The predominantly sandstone peaks of the Swartberg are also inhabited by Umbilicariae. *U. cylindrica* and *U. polyphylla* have been found on the Wagenboomberg at 6,500 ft. alt. Also, a small fragile form of the nitrophilous *U. hirsuta* Ach. em. Frey is recorded from the Kreasberg at 5,000 ft. alt.

CEDARBERG.

The localities in which Umbilicariae occur in the Central Cedarberg appear to be widely scattered. The Umbilicariae in this range attain profusion only above an altitude of 5,900 ft. This may be due to the occurrence of mist which is said to envelop the higher peaks and ridges periodically. The only substrate on which these lichens were found was Table Mountain Sandstone, some of which was more or less quartzitic.

Although the most extensive populations of Umbilicariae were found on the upper sandstone stratum above the "shale band" some of these lichens were seen on the lower sandstone stratum. An isolated population of *U. papulosa* var. *rubiginosa* and *U. hirsuta* was found on sheltered sandstone faces on an outcrop on the eastern side of the Middelberg ridge near the head of Boskloof (4,500 ft. alt.). The outcrop was somewhat shaded by a large Widdringtonia. The thalli of *U. papulosa* var. *rubiginosa* exhibited a colour range from grey to reddish brown and were generally larger than those found on Table Mountain, being about 4 cm. in diameter. Further plants of these two species were found on the outcropping lower sandstone stratum in the vicinity of the Welbedacht Cave (5,000 ft. alt.). Frey (1933) describes *U. hirsuta* as markedly nitrophilous and regards it as a "Charakterflechte" of places where birds roost ("Vogelsitzplatze") in the higher Swiss Alps. However, he also records it from dripping rock faces where, he suggests, it perhaps obtains its minimal nitrogenous requirements from the seepage water. Consequently, it appears that the species can tolerate a low nitrogen supply, although it can utilise greater supplies to advantage. In the Cedarberg localities no great amount of bird droppings was seen above the colonies of the lichen.

The vertical faces of the upper sandstone stratum on the south corner of the Cedarberg Tafelberg (5,900—6,200 ft. alt.) have been colonised by extensive populations of Umbilicariae. The more exposed western face supports less of these lichens. The most luxuriant growth of Umbilicariae was found on large sandstone boulders and the main rock faces of the south-east face of the Tafelberg about the saddle (6,000 ft. alt.) between the Tafelberg and the Spout. The locality is cool and shaded for the greater part of the day and these rock faces are said to be ice-covered in winter. The most frequent species here is *U. Schelpei* Frey which is mixed with *U. decussata* Zahlb., *U. subglabra* Harms and *U. laevis* var. *Garsidei* Frey. The thalli were noticeably larger (up to 7 cm. diam.) on the sites of periodic water flushes over almost vertical rock faces. Frey (1933) indicates that *U. decussata* and *U. subglabra* are somewhat nitrophilous in Switzerland, and it is not improbable that some nitrogenous material would be washed down such flushes from bird droppings on the summits of the cliffs.

Boulders in deep shade in the large sheltered gully (Gully Route) on the south-eastern corner of the Tafelberg support a sparse population of the light-coloured *U. vellea* Ach. which was not found elsewhere on the mountain. Although this species is hygrophilous in Europe and reaches maximum development of the thalli along seepage lines (Frey 1933, 1949), the Cedarberg locality is hardly very moist for long periods but its cool sheltered situation would expose it to less desiccation than in other parts of the mountain.

The summit plateau of the Cedarberg Tafelberg (6,400 ft. alt.) has been eroded into deep crevices one to five metres deep with the consequent formation of rock bowls with overhanging rims. Extensive areas of closely adjacent rock "mushrooms" also occur on the summit. The shaded vertical walls of these various structures support sparse populations of *U. Bolusiana* Frey, *U. laevis* var. *Garsidei* and *U. papulosa* var. *rubiginosa*. The individual thalli are invariably small (±2 cm. diam.), a phenomenon probably due to adverse microclimatic conditions. *U. Bolusiana* has also been recorded from the Keeromberg and the Bokkeveld Sneeuwkop at altitudes of about 6,000 ft.

NATAL DRAKENSBERG.

U. haplocarpa is the only species of the genus which has been found on the Drakensberg as yet. The small grey thalli (± 2 cm. diam.), which are usually found bearing apothecia, occur in small scattered populations on east aspect faces of amygdaloidal basalt at 9,800 ft. alt. in the Mont-aux-Sources area. Despite extensive examination of basalt faces below the edge of the summit plateau and of the Cave Sandstone cliffs at lower altitudes, no Umbilicariae were found at altitudes lower than 9,800 ft.

DISCUSSION.

It will be seen from these observations that the known South African species of Umbilicaria are confined to the higher mountain regions which have a fairly high rainfall. With the exception of *U. haplocarpa*, they all occur within the winter rainfall area.

Their distribution indicates that they require a temperate or subalpine climate. In South Africa and New Zealand (South Island), *U. cylindrica*, *U. polyphylla* and *U. vellea* are restricted to temperate or subalpine mountain environments. *U. vellea*, *U. hirsuta* and *U. haplocarpa* are confined to climatically similar montane habitats in South Africa and South America.

The South African Umbilicariae occur on sandstone or quartzitic sandstone substrates, with the exception of *U. haplocarpa* which occurs on Drakensberg amygdaloidal basalt. However, *U. hirsuta* and *U. decussata* are recorded from Popocatepetl on an andesite substrate; *U. vellea* and *U. haplocarpa* have been found on a substrate of Metamorphic rocks in the Nevados de Anconquija in the Argentine (Frey, 1949). *U. hirsuta*, *U. cylindrica* and *U. subglabra* occur on siliceous substrates in France (Hamand, 1909). Frey (1933) records *U. cylindrica* and *U. polyphylla* as members of the *Umbilicarietum hyperboreae* in Switzerland, on granite and gneiss blocks. It may be concluded that some of the species of Umbilicaria are able to grow on a wide variety of reasonably stable rock substrates with the exception of calcareous rocks. Consequently it appears that their distribution is affected more by the prevailing micro-climatic conditions than by the nature of the substrate.

Umbilicaria thalli are capable of absorbing moisture from rain and mist and also in the form of water vapour, as has been shown by Scofield and Lawrence (1943). The assimilation rate in Peltigera (Ellee, 1939) and the respiration rate in Parmelia (Neubauer, 1938) both increase with increasing water content, maxima being obtained in saturated thalli. Although no data are available for Umbilicaria thalli it seems probable that the assimilation and respiration rates of thalli of this genus would increase with an increase in water content of the thalli.

Growth of Umbilicaria thalli is slow; Fink (1917) estimated that the average annual increase in diameter of thalli of *Umbilicaria pustulata* in Kentucky was 0·36 cm., although higher rates of growth were observed. However, the rate of growth would depend largely upon water supply. Observations on the distribution of these lichens on the Cedarberg Tafelberg indicate that the maximum thallus size of individuals occurs in sheltered positions on the sites of periodic water flushes. In such localities the evaporating power of the atmosphere in the micro-climate would be lower for longer periods than on exposed faces. On Table Mountain, thalli of *U. papulosa* var. *rubiginosa* attain a larger size and are more frequent about the summit plateau, where precipitation is higher and mist more common than at lower altitudes on the same substrate. It is concluded that growth of Umbilicaria thalli is favoured by high and frequent precipitation and infrequent occurrence of very low relative humidities in the micro-climate.

Light intensity is another factor which might affect the rate of thallus growth. At very low light intensities it is possible that specifically characteristic thalli would not be formed. It appears that many of the known South African Umbilicariae are able to tolerate a wide range of light intensities while preserving their characteristic thallus form. Hence, it seems most probable that light intensity is of less importance than water supply and the evaporating power of the atmosphere, in controlling the rate of thallus growth and affecting the distribution of these lichens. This view is in accord with the conclusions reached by Plitt and Pessin (1924) on factors influencing the distribution of some corticolous lichens in Maine.

Bitter (1899) records an increase in the production of isidia by Umbilicaria thalli covered with fallen pine needles. Such increased isidial production may be correlated with increased shade or with increased humidity in the immediate micro-climate of the thalli, or both. These isidia, when detached from the parent thallus, may function as propagules. However, Umbilicaria isidia are frequently devoid of algae (Frey, 1929, 1949) and such isidia consequently cannot effect direct propagation of the thallus. It is not known whether or not there is any correlation between isidial production on one hand and light intensity and water supply on the other, besides the extreme case cited. Fragments of the thallus and various "buds" may be detached from the parent thalli and function as propagules.

The lack of continuous observation of relative humidities and light intensities in the micro-climates prevailing where these lichens occur, precludes any detailed information on the limits of tolerance towards the various factors of the environment shown by different species. However, preliminary observations indicate that, among the species of the South African Umbilicariae, *U. papulosa* var. *rubiginosa* exhibits the widest limits of tolerance to a variation in climatic conditions.

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SUMMARY.

The habitats of the known species of the South African Umbilicariae are described. They occur in montane regions with a fairly high rainfall

and with a temperate or sub-alpine climate. Most of the species occur on sandstone substrates. Growth of Umbilicaria thalli seems to be favoured by high and frequent water supply by rain and mist, and the infrequent occurrence of low relative humidities in the micro-climate. Light intensity appears to be a factor of less importance.

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